Name ____ AP Chemistry

Strength of Acids & Bases and pH Calculations

Strength of Acids & Bases

The strength of an acid or base is defined by the equilibrium position of its dissociation as described by K_a or K_b. Strong acids/bases have an equilibrium that lies far to the right (or with the products) while weak acids/bases have an equilibrium that lies far to the left (or with the reactants). The value of K_a or K_b indicates the strength of the acid or base. The following table summarizes the key points of the difference between strong and weak acids or bases:

Comparison of Strong and Weak Acids			
Type of Acid (HA)	*Reversibility of Reaction*	*K_a Value*	*Species in Solution with HA dissociates in H_2O*
Strong			
Weak			

Comparison of Strong and Weak Bases			
Type of Base (B)	*Reversibility of Reaction*	*K_b Value*	*Species in Solution with B dissociates in H_2O*
Strong			
Weak			

Remember that for each acid-base reaction, there are two pairs of acids and bases: acid and its conjugate base and base and its conjugate acid. There is a relationship between the acid or base and its conjugate partner:

Below are the strong acids and bases that you are responsible for knowing:

Strong Acids	**Strong Bases**

Ionization of Water, pH and pOH

Recall that water is amphoteric, meaning it can behave as an acid or a base. This property can be seen through the autoionization of water:

$$2\ H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + OH^-\ (aq)$$

This reaction has an equilibrium constant, called the ionization of water constant of dissociation constant for water (K_w):

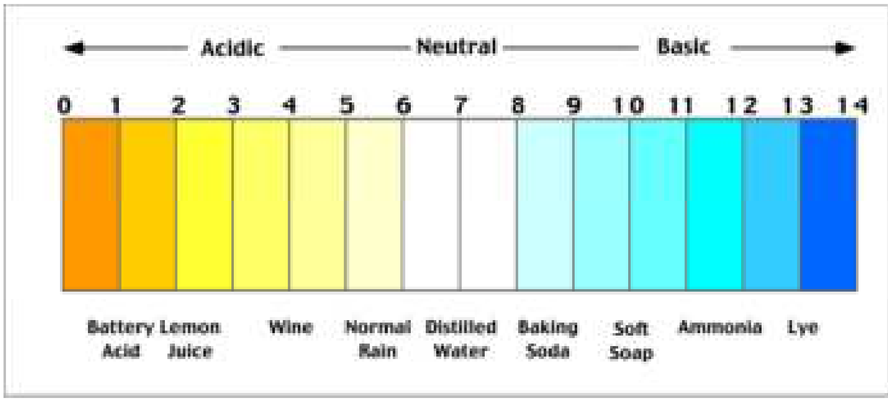
An experiment at 25ºC for pure water found that $[H_3O^+] = [OH^-] = 1.0 \times 10^{-7}$ M, making K_w equal to 1.0×10^{-14}. Remembering Arrhenius' definition of acids and bases, an acidic solution contains H^+ ions while a basic solution will contain OH^- ions. Using this information along with value of K_w, the $[OH^-]$ or $[H_3O^+]$ can be calculated along with type of solution can be determined, creating three possible situations:

<u>Example #1</u>

Calculate $[H^+]$ or $[OH^-]$ as required for each of the following solutions at 25ºC, and state whether the solution is neutral, acidic, or basic.

(a) 1.0×10^{-5} M OH^-
(b) 1.0×10^{-7} M OH^-
(c) 10.0 M H^+

Another manner to describe the acidity or basicity of a solution is through a pH or pOH scale. pH scale is a logarithm relationship between pH and hydronium concentration, ranging from 0-14 and can be calculated by the following formula:



Relationship between $[H^+]$ and pH:

A similar approach can be used with hydroxide concentrations with a pOH scale, which is the opposite of the pH scale. pOH can be calculated with the following formula:

Finally, pH and pOH, when summed together, will equal 14.

<u>Example #2</u>

Calculate the pH and pOH for each of the following solutions at 25ºC.

(a) 1.0×10^{-3} OH^-
(b) 1.0 M OH^-

pH and pOH Calculations of Strong Acids and Bases

Recalling that strong acids and bases dissociated completely with mixed with water, the $[H^+]$ or $[OH^-]$ concentration is going to be equal to the concentration of the acid or base, which will not remain in the solution after the initial reaction. Therefore, the pH or pOH of a strong acid or base can be calculated from the concentration of the acid or base itself.

Example #3

Calculate the pH of 0.10 M HNO_3 and of 5.0×10^{-2} M NaOH.

Part I Practice

1) Rank the following acids or bases in order from weakest to strongest:
   (a) Acid: HCl, H_2O, HCN, HNO_2, HOC_6H_5
   (b) Base: Cl^-, H_2O, NO_2^-, CN^-, $OC_6H_5^-$

2) Calculate $[H^+]$ for each of the following solutions and indicate where the solution is acidic, basic, or neutral:
   (a) $[OH^-] = 0.00045$ M
   (b) $[OH^-] = 8.8 \times 10^{-9}$ M

3) Calculate $[H^+]$ and $[OH^-]$ for each solution at 25ºC and identify each solution as neutral, acidic, or basic.
   (a) pH = 7.40
   (b) pH = 15.3
   (c) pOH = 5.0
   (d) pOH = 9.60

4) Fill in the following table:

$[H^+]$	$[OH^-]$	pH	pOH	Acidic or Basic?
7.5×10^{-3} M				
	3.6×10^{-10} M			
		8.25		
			5.70	

5) Calculate the pH of each of the following solutions:
   (a) 8.5×10^{-3} M HBr
   (b) 1.52 g of HNO_3 in 575 mL of solution
   (c) a solution formed by mixing 10.0 mL of 0.100 M HBr with 20.0 mL of 0.200 M HCl

6) Calculate $[OH^-]$ and pH for each of the following solutions:
   (a) 0.012 M KOH
   (b) 1.565 g of KOH in 500.0 mL of solution
   (c) a solution formed by mixing 10.0 mL of 0.015 M $Ba(OH)_2$ with 40.0 mL of 7.5×10^{-3} M NaOH

7) Calculate the concentration of the following aqueous solutions:
   (a) NaOH with a pH of 11.50
   (b) HI with a pH of 1.75

pH and pOH Calculations of Weak Acids and Bases

The pH or pOH of a weak acid or base cannot be calculated directly from the concentration of the acid or base since all of the acid or base does not dissociate to form H^+ or OH^-. The equilibrium reaction of the acid or base must be considered. Below are suggested steps to follow when solving these types of questions:

(1) Write the reaction of the acid or base with water.
(2) Write the equilibrium expression in terms of reactants and products (without numbers).
(3) Set up an ICE chart with appropriate values and variables.
(4) Solve for x.
(5) Solve for pH (weak acid) or pOH (weak base).

<u>Example #4</u>

Calculate the pH of 0.25 M HCN.

<u>Example #5</u>

The pH of a 0.20 M solution of H_2NNH_2 is 11.38. Calculate the K_b for H_2NNH_2.

Percent Dissociation

To quantify the dissociation of an acid or base, the percent dissociation can be calculated. The percent dissociation of an acid or a base is calculated using the following formula:

Strong acids or bases will have a high percent dissociation while weak acids and bases will have a low percent dissociation.

Example #6

The percent dissociation of an acid (HA), which is 0.100 M is 2.5%. Calculate the K_a of the acid.

Part II Practice

1) Barbituric acid ($K_a = 1.1 \times 10^{-4}$) is used in the manufacture of some sedatives. For a 0.673 M solution of barbituric acid, calculate $[H^+]$, $[OH^-]$, and pH.

2) Consider sodium acrylate ($NaC_3H_3O_2$). K_a for acrylic acid (its conjugate acid) is 5.5×10^{-5}.
   (a) Write a reaction to show its basic nature in water.
   (b) Calculate K_b of the reaction.
   (c) Find the pH of a solution prepared by dissolving 1.61 g of $NaC_3H_3O_2$ in enough water to make 835 mL of solution.

3) For propionic acid ($HC_3H_5O_2$, $K_a = 1.3 \times 10^{-5}$), determine the concentration of all species present and the pH of a 0.100 M solution.

4) Calculate the pH of a 0.050 M $(C_2H_5)_2NH$ solution ($K_b = 1.3 \times 10^{-3}$).

5) Calculate the percent ionization of propionic acid in solutions of each of the following concentrations (hint: see question #3 for K_a):
   (a) 0.250 M
   (b) 0.100 M

6) A 0.100 M solution of chloroacetic acid ($ClCH_2COOH$) is 11.0% ionized. Using this information, calculate $[ClCH_2COO^-]$, $[H^+]$, $[ClCH_2COOH]$, and K_a for chloroacetic acid.